Lange Coupler Product Development

Design Report

12/20/04

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Program Overview

The goal of this effort is to develop a Lange Coupler product. This effort is part of a larger goal of developing a family of standard products that may include couplers covering several different frequency ranges, spiral inductors and other products. This current project has two couplers, one with a 50 ohm terminated port, and the other with all open circuit ports.

The Coupler will use the Ultra Source under bridge technology which is a market differentiating thin film process. It allows for interconnects in very fine geometries. The benefit of this process for the coupler is that it will eliminate the need for very tough wire bonding on small pads. This is a big advantage for most users since wire bonds on Lange Couplers are a frequent source of failure.

The design effort started on 11/8/04 on Ultra Source PO number 25890. The design effort is to be completed on 12/20/04.

Electrical Performance Goals

The goal is to achieve 7-11 GHz bandwidth with equal power split between the coupled arms. The power split is to be 3dB + Metal Losses with an error between the coupled ports of +/- 0.5dB. The ports are to have a VSWR of better than 1.5:1 and Isolation of 15dB or better.

Approach

The design approach is to use microwave circuit EDA software. MPT has standardized on Microwave Office. Also, detailed electromagnetic finite element simulations will be conducted using HFSS. Physical design will be done in AutoCAD2005.

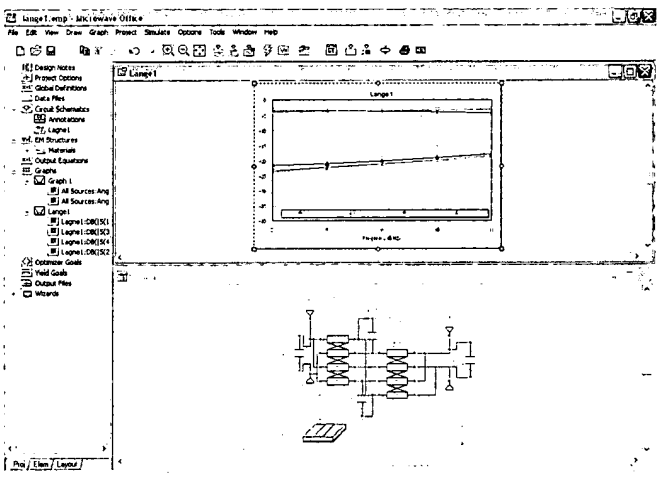

Figure 1. Screen shot of Microwave Office model used in the coupler design.

Figure 1 shows a screen capture of Microwave Office and one of the Lange Coupler models used in the design effort. This software is very capable and has a feature set that allows the design of many different microwave products such as amplifiers, oscillators and filters to name a few. This software was used to improve electrical performance by optimizing the line widths, gaps and lengths of the coupler. This tool is very fast and can perform full simulation in 1-10

seconds. This allows many thousands of variations to be considered and an interim improved design to be generated. Microwave Office is accurate, but improved accuracy is possible by using other software tools.

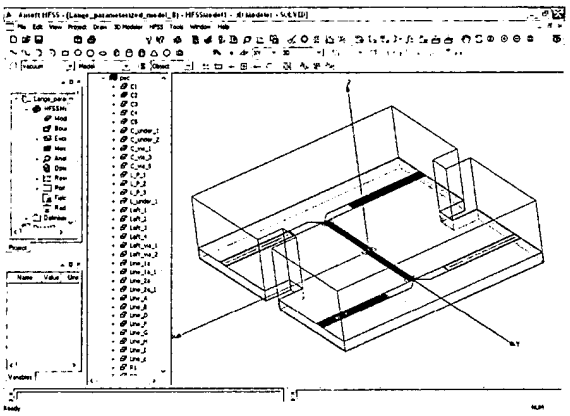

Figure 2. HFSS model of the coupler.

Next, the interim improved design was implemented in High Frequency Structure Simulator (HFSS). This is an electromagnetic finite element simulator and predicts scattering parameters for microwave circuits. This tool was used to fine tune the performance. It takes up to several hours for HFSS to converge to a solution. Also, it takes many hours to build up the model. Therefore, this tool is best used to make small adjustments to perfect a design. This tool is very accurate, but the designer must capture the important physical features to ensure accurate results.

Besides the modeling effort, an existing Lange Coupler was supplied to MPT for evaluation. This device was mounted on a carrier plate using Ablestik 84-1 conductive epoxy. Also, CPW to microstrip transitions were attached to the carrier using the same 84-1 epoxy. The transitions are compatible with microwave probe stations.

The approach is to:

1) Measure the existing Lange Coupler on a microwave probe station and Veeco.
2) Model the coupler in HFSS.
3) Compare the measured data vs. model and, if required, improve the model.
4) Perform detailed design of the improved coupler using the model that has been verified by measured data.

Results

First, let's consider measurements on the existing coupler. After the coupler was mounted on the metal carrier, it was measured on the Veeco NT3300 surface topography machine to measure line width sand gaps. This is important since it will allow us to know the physical configuration of the coupler that will be measured on the probe station. Figure 3 shows the topography of the center section of the coupler. It

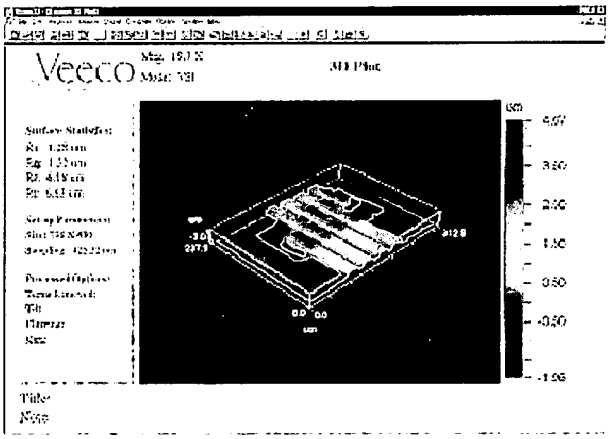

Figure 3. Surface Topography of the Coupler.

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shows the section with the under bridge, the SiN, and the coupled lines. Also, note the vias connecting the top metal to the under bridge metal.

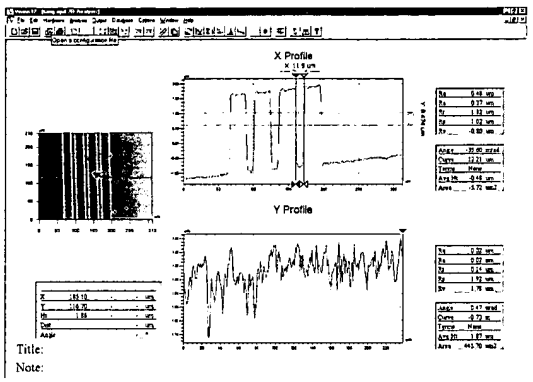

Figure 4. Veeco measurement of the coupled lines widths and gaps.

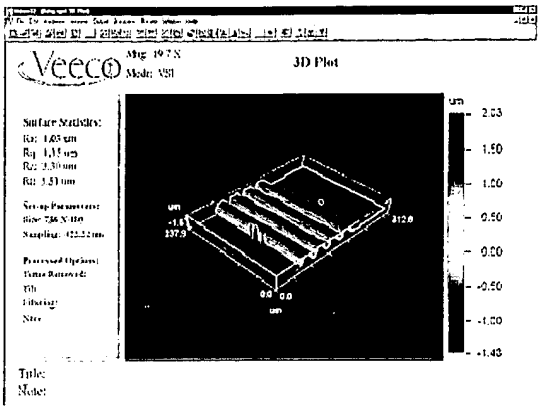

Figure 5. Graphic of the coupled line section

Figures 4 and 5 show the measurements of the coupled line section. Note how the coupled line section has four lines and three gaps. From several measurements along the length of the line, it was determined that the line width is 23.4um and the gap is 11.7um.

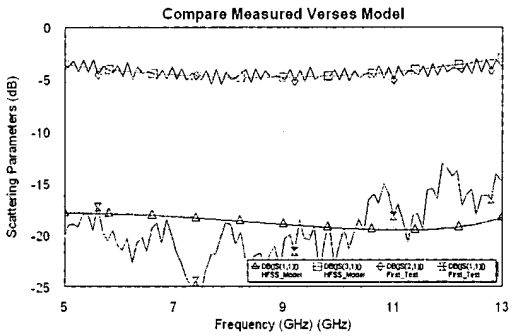

Figure 6. Comparison of the measured performance and HFSS predictions.

Next, measurements were made of the existing Lange Coupler. A microwave probe station and an Agilent 8722ES vector network analyzer were used.

HFSS was used to model the coupler that was measured using the Veeco system. Figure 6 shows a comparison of the measured data and the modeled results. Note how the agreement is very good for the signal path that was measured. The insertion loss curves follow each other nearly exactly. The return loss is also in good over the 7-11GHz range.

Based on these results, the design of an improved coupler can proceed with a high degree of confidence in the results.

Improved Design

An improved design was developed using the procedure outlined above. After initial optimization in Microwave Office, the design was modeled in HFSS. Many different HFSS simulations were conducted to arrive at the final optimized

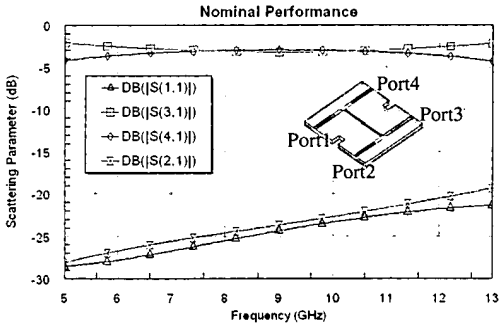

Figure 7. HFSS Model of the improved coupler.

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design. The improved design predicts full compliance with all the performance goals. In fact, there is margin which is important for any design.

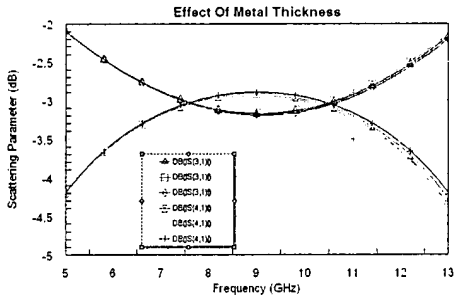

Figure 8. Effect of line thickness variation.

The performance predictions in Figure 7 are the substantially the same for the coupler with the terminated port and the four port coupler.

A simulation study was conducted to determine the effects of line thickness variation on coupler performance. The concern is that the electrical performance, i.e. coupling coefficient, may change as the line thickness changes as a production process variation. HFSS was used for this study. The simulation used 40KÅ, 45KÅ and 50KÅ for the line thickness. Figure 8 shows the results. The results show that the coupling varies very slowly with line thickness changes. This shows that if the deposition of metal can be kept to within 5KÅ accuracy, the coupler performance will not be affected significantly.

Summary

In summary, MPT has completed the analysis of the existing coupler and the design of the improved coupler. The improved coupler performance predictions show specification compliance with all requirements.

Also, MPT delivered more than promised. For example, probe station measurements of the device were conducted using a high precision microwave probe station. Originally, a test fixture was going to be used which would have required Ultra Source to fabricate custom substrates and a test fixture. Also the test fixture results would not have been as accurate as the probe station results. The use of a probe station has resulted in much more accurate measurements and is beyond what was promised.

Furthermore, MPT was able to perform detailed topography measurements using a Veeco NT3300. This is an advanced non-contacting 3D surface topography measurement instrument. In fact, it is considered the most advanced surface metrology system available and measures heights down to Angstroms with vertical resolution to 0.1 nm. It is used in measurement of MEMS, semiconductor packaging, medical devices, automotive systems and many other applications.

The Veeco tests were very important since it allowed MPT to accurately characterize the existing coupler design from Ultra Source. This permitted a model to be built using the exact line widths and gaps measured on the sample. These dimensions were used in a HFSS model. The HFSS results were compared to the probe station measured results of the same coupler used in the Veeco topography tests. This allowed MPT to tie the physical dimensions to modeling and back to the measured data.

Also, MPT performed a manufacturability study on the line thickness. This is also beyond what was promised and is very helpful in establishing process control requirements.

An AutoCAD design of the coupler is complete. The design is ready for fabrication.

Before proceeding, MPT and Ultra Source will need to execute the consulting and royalty agreement. Once the agreement is executed, MPT will transfer the AutoCAD design files. Ultra Source will then determine when/if to proceed with fabrication based upon the results of this report and the AutoCAD design files.

Disclaimer

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